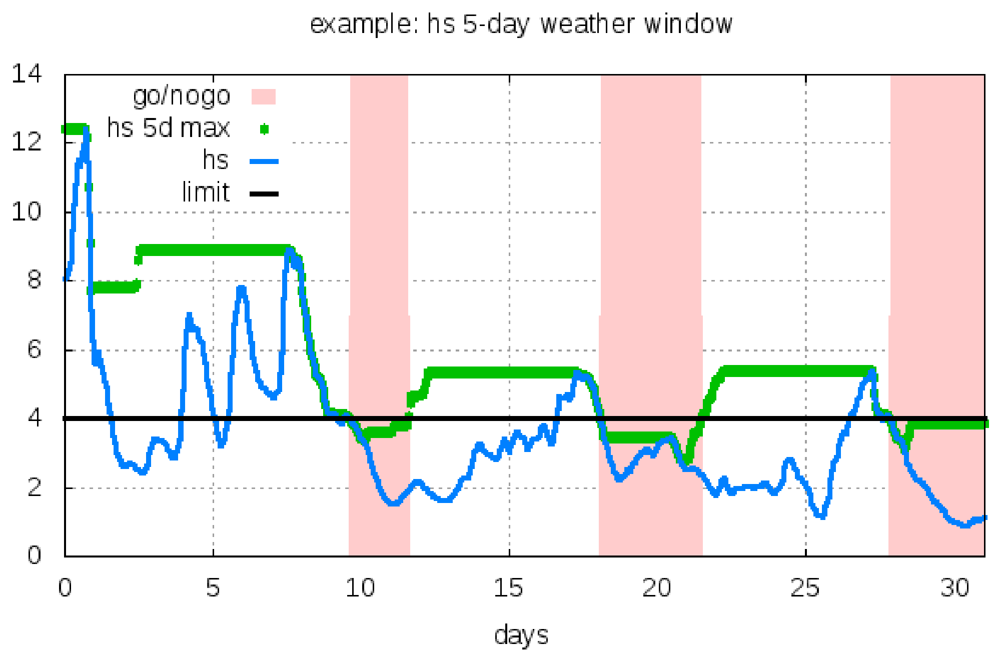
DMI Report 19-15

Weather window statistics for two locations along the Southwest Greenland coast

Jacob Woge Nielsen and Mads Hvid Ribergaard



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Author(s)
Jacob Woge Nielsen and Mads Hvid Ribergaard

Other contributors

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Content

Abstract

Weather window statistics for specific maritime operations is calculated for two locations along the Southwest Greenland coast: near Cape Farewell and off Sisimiut. The statistics is based on 11 years (2006-16) of wind and wave information derived from operational weather and hindcast wave model runs at DMI. Statistics is given on a calendar monthly basis for March through June.
Sea ice turns out to be of major importance especially for the statistics for the northern location and is included as an add-on to the statistics. For both locations, the number of operation windows increases significantly from March through June.

Resumé

Statistik for vejrvinduer til specifikke maritime operationer beregnes for to positioner langs den sydvestlige grønlandske kyst: nær Cape Farewell og ud for Sisimiut. Statistikken beregnes ved hjælp af 11 års (2006-2016) vind- og bølgeinformation afledt af vejr- og bølgemodeller, der er kørt ved DMI. Statistikken vises for kalendermånederne marts til juni.
Tilstedeværelsen af havis viser sig at være vigtig for specielt den nordlige lokation og er inkluderet som en tilføjelse til statistikkerne. For begge lokaliteter stiger antallet af operationsvinduer markant fra marts til juni.

Introduction

We calculate weather window statistics for two off-shore Southwest Greenland locations using 11 years of hourly model data of roughly 5km spatial resolution. Time series for nearest model grid point is used for the statistics. The station locations and weather window criteria are as follows

- Southern location (off Cape Farewell): 59 46.9849N ; 047 03.7652W
  - Weather windows of 5 days or more with:
    - Mean 10m (surface) wind speed < 12 m/s
    - Significant wave height < 4m

- Northern location (off Sisimiut): 67 22.0000N ; 054 02.0000W
  - Weather windows of 3 days or more with
    - Mean 10m (surface) wind speed < 12 m/s
    - Significant wave height < 4m

Wind gust and maximum wave height are not considered.

As it turns out, sea ice on especially the northern location impacts the statistics. Waves may be low due to the presence of sea ice, giving a false impression of operability. Therefore we extend the statistics with an additional condition on sea ice:

- Sea ice concentration < 30%

and present results with and without this condition. This same limit is used in the wave model to decide whether a location is to be regarded as ice-covered or not.

Other important factors for safe maritime operations could be icebergs, growlers and fog. Neither of these is considered within this report.

The statistics is meant to be used for long term planning and not for a specific event.

Method: Weather windows

We calculate weather windows as follows. Let x be a time series of hourly values

$$x(t),\ t = 1,2,\ \dots\ N$$

Given a critical level X0, the percentage of $x<X0$ may be taken to represent the probability of obtaining a 1 hour window when picking a random time. For windows of length *n* hours, we replace $x(t)$ with $y(t)$ given by

$$y(t) = \max\ (x(t),\ x(t+1),\ \dots,\ x(t+n-1))$$

and apply the same procedure. The percentage of $y(t)<X0$ now represents the probability of obtaining an *n* hour window from a random starting time. To have *N* possible windows in total, the series must be expanded to *N*+*n* values. If that is not possible, the statistics is based on *N*-*n* possible windows.

The windows thus obtained may overlap. For example, a six-hour window transforms into four three-hour windows:

Full window	1	2	3	4	5	6
3-hour windows	1	2	3			
		2	3	4		
			3	4	5	
				4	5	6

This assumes a go/no-go decision to be taken every hour. With decision taken on a less frequent basis, the statistics may change. This is examined by picking only every *m*'th line in the table above, *m* being the number of hours between operative decisions.

To combine two criteria, using data types represented by time series $x_1(t)$, $x_2(t)$ and critical levels X_1, X_2, we transform both corresponding $y_i(t)$ into binary series $z_i(t)$:

$$z_i(t) = 0 \text{ if } y_i(t) >= X_i$$
$$z_i(t) = 1 \text{ if } y_i(t) < X_i$$

The criteria are combined by

$$z(t) = z_1(t) * z_2(t)(\ \dots * z_3(t) * z_4(t) * \dots)$$

With this approach, z=1 if no critical level is exceeded, 0 otherwise. The percentage of z=1 is the weather window probability. As indicated, this procedure is easily extended to more criteria by multiplying all z_i, given that all series have same time range and step.

The procedure for a single parameter (wave height) and a single month is illustrated below. The original time series (blue) is converted to the 5-day maximum series (green), and further matched up with the 4m criterion (black) to give the weather window series (pink). The operability is the percentage of pink on the graph. For more parameters, only overlapping windows are operative.

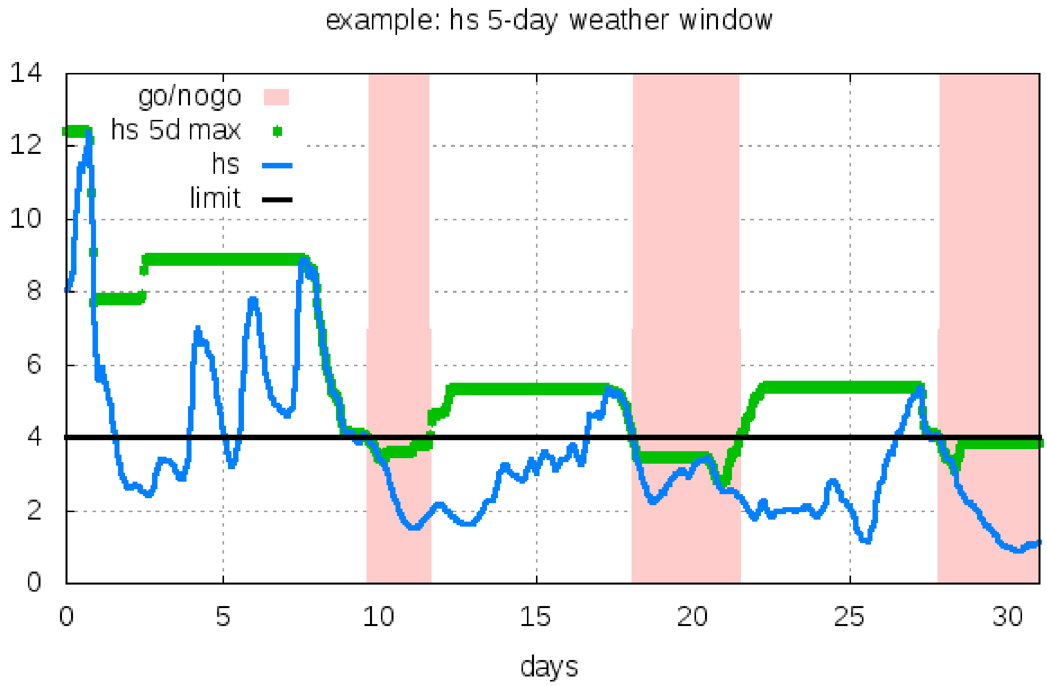

Figure 1. 5-day single parameter weather window determination. Blue= significant wave height, hs. Green= maximum value from now and 5 days ahead. Black= critical value, hs=4m. Pink= at least a 5-day window below critical value lies ahead.

Data: Weather and wave models

Weather model (HIRLAM)

The surface wind is provided by a regional version of DMI-HIRLAM (Undén et al., 2002; Yang et al., 2005) called K05, dedicated for Greenland (Figure 2, blue box). The model has 5 km spatial resolution, and was operational during the study period and until DMI-HIRLAM was phased out August 2018. K05 was run in operational mode 4 times daily using boundary conditions from the European Centre for Medium-Range Weather Forecasts (ECMWF). The K05 archive serves further as input for regional wave modelling as described below. It also contains daily information on sea ice, which has been imported on routine basis from a variety of sources relying on satellite observations (NCEP, OSISAF), error-checked, and used as surface boundary in the weather forecast.

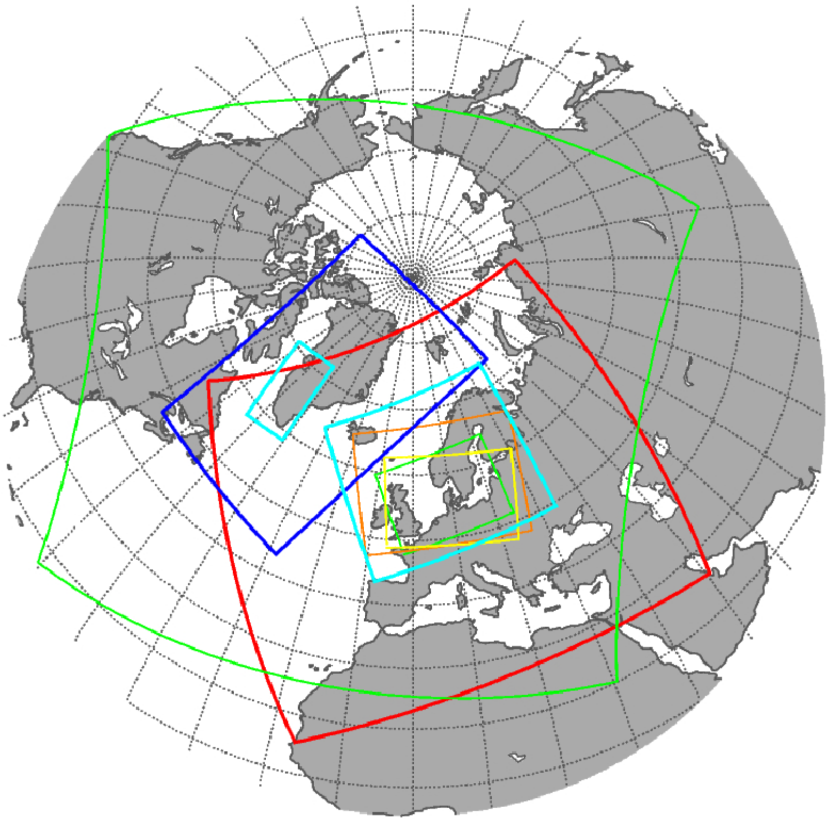

Figure 2. Operational weather models at DMI, January 2014. In the present report, data from the 5 km DMI-HIRLAM-K05 (dark blue) surrounding Greenland is used. The 15 km resolution DMI-HIRLAM-T15 (green) provides input for mesoscale wave modelling as described below.

Wave model (WAM)

The significant wave height is provided by a project set-up of the DMI operational off-shore wave model DMI-WAM. While the operational set-up (described in Nielsen, 2003; updates and details publicised at http://ocean.dmi.dk/models/wam.uk.php) focuses on Danish waters, the project set-up aims specifically at utilising the K05 DMI-HIRLAM surface wind and ice cover to provide more detailed insight in waves around Greenland.

In the project, an update of the operational DMI-WAM model code was used, with – amongst other refinements – a more suitable treatment of polar and sub-polar model grids. The operational code is WAM Cycle4.5 (Günther, Hasselmann and Janssen, 1992). The revised version used for this study is WAM Cycle 4.5_3 (Günther & Behrens, 2011).

The wave model project set-up includes a North Atlantic model of 25 km resolution, with an embedded 5km Greenland regional model covering the area 56-80N, 80-16W. The model areas are indicated by blue resp. green in Figure 3. The North Atlantic model is forced by the 15 km resolution T15 version of DMI-HIRLAM (cf. Figure 2), and has as its main purpose to calculate the wave energy (e.g. swell) propagating into Greenland waters from distant storms. The Greenland model is forced by the 5 km resolution K05 version of DMI-HIRLAM, with the high resolution of the weather model allowing effects of steep coastal orography on off-shore wind and waves to be calculated. The katabatic winds thus generated are known to be able to persist far off-shore Greenland, and coarse-grid weather models are known not to capture this. While WAM is an off-shore wave model, mainly applicable outside the breaker zone, it does have the option of depth-induced wave breaking and thereby loss of wave energy. This option is switched on in the Greenland model only. Interaction with sea current and effects due to varying sea level caused by tides or storms are not incorporated. Interaction with sea ice is included using daily sea-ice information, re-initialised at midnight and readily obtained through the weather model. Wherever more than 30% sea ice is present, wave energy is eliminated.

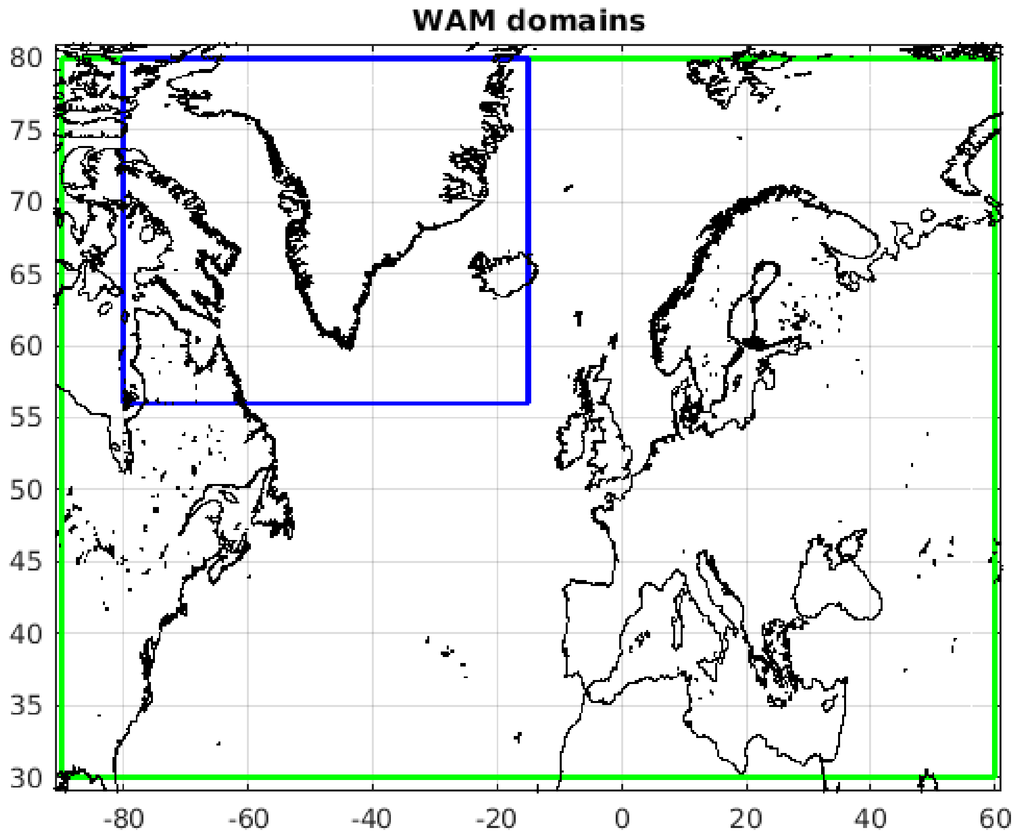

Figure 3. DMI-WAM set-up used for the present report. It consists of a 25km North Atlantic model (green, a subset of a global model), with an embedded 5km Greenland model (blue). Ice is masked out on a daily basis, using information from the atmospheric forcing models DMI-HIRLAM-T15 and DMI-HIRLAM-K05, respectively.

WAM calculates production, propagation and dissipation of wave energy, with the surface wind as energy source. The significant wave height, which in observation terms corresponds to the mean of the highest third of the waves, is calculated as a function of the total wave energy. The maximum wave height, which in observation terms is the highest wave in a record, is not calculated by the WAM model, which does not address single waves.

The 11-year wave model simulation was carried out in 2017. After 3 months of spin-up (2005/10-2005/12) the production period (2006-16) was stored for future use.

Results

Statistical monthly weather windows based on 11 years of data are presented in Tables 1 and 2. Averages are calculated for the calendar months March, April, May and June.

Southern location (Table 1).

- Windows on 5 days or more with:
    - Mean 10m wind speed <12 m/s
    - Significant wave height < 4m

Northern location (Table 2).

- Windows on 3 days or more with:
    - Mean 10m wind speed <12 m/s
    - Significant wave height < 4m

An additional condition on sea ice concentration is examined, viz.:

- Sea ice concentration < 30%

The sea ice information is updated once a day. It is included in particular in order to render the result at the northern location meaningful, since sea ice in some months may be the main obstacle for operation. The inclusion was straightforward, as described in the Chapter on Method.

Three decision intervals are examined: hourly, 6-hourly (at 00, 06, 12, 18z), and daily (at 00z). The results for the three choices are very similar. This proves that the statistics is solid and usable for long term planning. However, for a specific operation it is always advised to use the newest available prognoses, as a specific event does not necessarily follow the statistical mean behaviour, and that the forecast skill decreases with the forecast length.

For the southern location (Table 1), the chance obtaining a 5-day weather window is very low in March (1.3%) and April (4.8%). It increases to 16.1% in May and 36.2% in June.
There is little or no impact from sea ice.

For the northern location (Table 2), the chance of operability obtaining a 3-day weather window is roughly 85-90% in all months. The wave and wind climate is much less rough.
However, when adding the constraint of low sea ice concentration the chance of operability drops in March (11.2%), April (40.0%), and May (77.9%).

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Cape Farewell, lat=59°46.9849'N, lon=47°03.7652'W								
Month	Windows	Good	Bad	Good (%)	Sea Ice	Sea Ice (%)	IceGood	IceGood (%)
1hr decision interval								
March	744	18	726	2.3	14	1.8	10	1.3
April	720	37	683	4.8	23	3.2	37	4.8
May	744	124	620	16.1	0	0.0	124	16.1
June	720	264	456	36.2	0	0.0	264	36.2
6hr decision interval								
March	124	3	121	2.2	2	1.8	2	**1.2**
April	120	6	114	4.7	4	3.2	6	**4.7**
May	124	21	103	16.3	0	0.0	21	**16.3**
June	120	44	76	36.5	0	0.0	44	**36.5**
24hr decision interval								
March	31	1	30	2.3	1	1.7	0	1.1
April	30	2	28	5.1	1	3.3	2	5.1
May	31	5	26	15.6	0	0.0	5	15.6
June	30	11	19	36.4	0	0.0	11	36.4

Table 1. Statistics for a 5-day weather window at the southern location (59°46.9849'N ; 047°03.7652'W) off Cape Farewell for March, April, May and June. Criteria are wind speed <12 m/s and significant wave height < 4m.The 6-hour decision interval with an additional condition on low ice concentration is highlighted.

Explanation to the tables:

- Windows: Number of possible weather windows
- Good: Number of weather windows found
- Bad: Number of windows including adverse weather
- Sea Ice: Number of windows including sea ice of concentration >= 30%
- IceGood: Number of possible weather windows when adding sea ice criterion

Sisimiut, lat=67°22’N, lon=54°02’W								
Month	Windows	Good	Bad	Good (%)	Sea Ice	Sea Ice (%)	IceGood	IceGood (%)
1hr decision interval								
March	744	661	83	88.4	638	85.5	84	11.2
April	720	612	108	84.5	365	50.4	292	40.0
May	744	655	89	87.7	74	9.7	582	77.8
June	720	657	63	91.0	19	2.6	645	89.4
6hr decision interval								
March	124	110	14	88.3	106	85.5	14	**10.9**
April	120	102	18	84.5	61	50.4	49	**40.1**
May	124	109	15	87.9	12	9.7	97	**77.9**
June	120	109	11	90.9	3	2.6	107	**89.3**
24hr decision interval								
March	31	27	4	87.9	27	85.7	3	10.3
April	30	26	4	85.9	15	51.2	12	40.4
May	31	27	4	88.4	3	10.1	24	77.9
June	30	27	3	91.4	1	2.7	27	89.5

Table 2. Statistics for a 3-day weather window at the northern position (67°22’N ; 054°02’W) off Sisimiut for March, April, May and June. Criteria are wind speed <12 m/s and significant wave height < 4m.The 6-hour decision interval with an additional condition on low ice concentration is highlighted.

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